THE EFFECT OF ILLUMINANCE ON THE REVERSAL TEMPERATURE IN THE DRONE FLY, ERISTALIS TENAX

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For over seventy-five years physiologists have attempted without success to unravel the mechanisms involved in the change of sign of reaction of organisms to light. In the reversal an organism which is normally photopositive, moving toward the light, becomes negative and avoids the light, or a normally photonegative organism, moving away from the light, becomes positive. Recently a study of this phenomenon in the drone fly, *Eristalis tenax,* was begun and additional facts have been discovered. According to Dolley and Golden (1947a), in an illuminance of 700 foot candles Eristalis is highly photopositive within a temperature range between approximately 10° and 30° C. Outside these limits it is highly negative. Above 30° C., the temperature at which Eristalis changes its reaction to light depends upon the sex and age of the flies. Females cease their positive reaction to light and become negative at a higher temperature than do males, and the younger the fly, the higher the temperature at which it becomes negative. Furthermore, according to Dolley and Golden (1947b), in an illuminance of 700 f. c., a correlation exists between the temperature at which Eristalis changes the sign of its reaction to light (its reversal temperature) and the temperature at which it dies (its lethal temperature). In general, the higher the reversal temperature, the higher the lethal temperature.

Since nothing was known about the relation between illuminance and reversal temperatures in any organism, a study of this relation in Eristalis was made. The results of this study are presented in this paper.

Materials and Methods

The apparatus used (Fig. 1) consists of a box (50 × 35 × 34 cm.) made of 6.3 mm. plywood. There are two main compartments, a light one, A, and a dark one, B. The two compartments, A, 6.25 cm. deep, and B, 15 cm. deep, are separated by a wooden slide, a, which can be raised. This slide is painted white on the side toward the light compartment. Above the light compartment are two sliding glass panels, b, c, 6.3 cm. apart. A thermometer, d, is inserted through a hole, e, at the level of the white floor, f.

The light compartment is lined with white cardboard on the bottom, two sides, and one end. The dark compartment is lined with dull black cardboard and has a removable wooden cover, g, through the center of which a thermometer, h, is inserted.

Beneath the detachable floor, i, of the light compartment are placed five wooden blocks, j (5 × 3 × 3 cm.), for support. These blocks rest on a sheet of galvanized metal, k.

The floor of the dark compartment, l, is a piece of black paper, beneath which are sheets of smooth cardboard, corrugated cardboard, and galvanized metal, m.

Below the metal sheets are two heat chambers, C, D, 12.5 cm. deep, lined with corrugated cardboard, m, and asbestos sheeting, o. The heat is supplied by two 100-watt Mazda lamps, p, each wired separately.

A 300-watt Mazda reflector spot lamp, q, is suspended over the center of the light compartment. By appropriate resistance the voltage of this lamp was kept

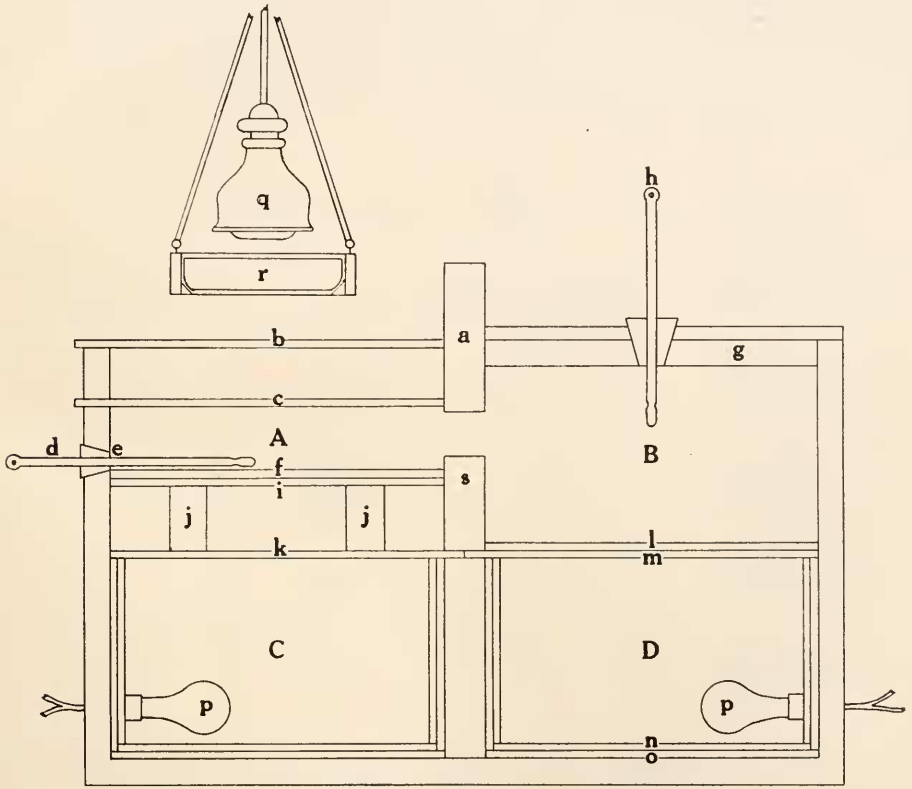

FIGURE 1. Sectional view of the apparatus used. See text.

constant at 105. A round glass dish, r, 23.7 cm. in diameter, containing distilled water to a depth of 2.5 cm., is beneath the lamp. This unit, q, r, can be raised or lowered to change the illuminance on the white floor, f. This illuminance was recorded by a Weston exposure meter.

In these experiments only young flies, 5 to 16 days old, were used. They were raised at room temperature, approximately 25° C., according to methods essentially similar to those previously described (Dolley *et al.*, 1937, p. 410), except that the larvae were cultured in cow manure.

The temperature at which the flies became negative to light in a known illuminance was determined. This was done for 270 males and 270 females in each of

the five illuminances: 250, 600, 800, 1200, and 1600 f. c. Only one observation was made on each fly.

All experiments were performed in a dark room. Before each experiment a record was made of the relative humidity of the air in the room. The same lamp was used in all of the experiments in all of the illuminances tested except those in 1200 f. c. The lamp used at this illuminance was, however, identical with the other one, so far as could be determined. A typical experiment was made as follows. The

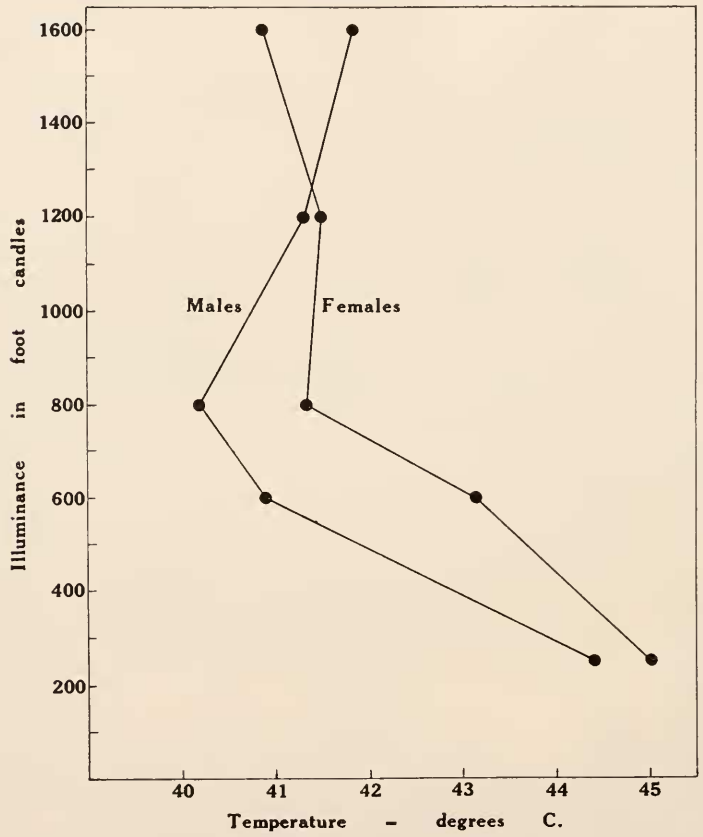

FIGURE 2. Graph showing the effect of illuminance upon the temperature at which reversal in reaction to light in Eristalis occurs. Note that the mean temperatures of the reversals decrease to a minimum at 800 f. c. In the males this decrease is followed by an increase, while in the females it is not. See text and Table I.

glass dish, r (Fig. 1), was filled with distilled water and the illuminating unit, q, r, was so adjusted that the illuminance desired was obtained on the floor, f, of the light compartment, A. The temperature in the dark compartment, B, was raised to between 35° and 37° C., that in the light compartment to 28° C. Throughout the experiment the temperature in the dark compartment was 6 to 9 degrees higher than that in the light compartment. Approximately 20 flies of the same sex, and with unclipped wings, were placed in the light compartment by sliding back the glass plates, b, c. These plates were replaced; the heating unit under the light chamber

was turned on, and the center slide, a, was raised, making an opening (18 × 4 cm.) connecting the two chambers.

As the temperature in the light chamber rose, the flies, becoming restless, crawled and flew about. Soon individuals moved out of the light into the darkness of the dark chamber. A fly was considered to have reversed when it had passed completely beyond the center ridge, s. When this occurred the investigator recorded to the nearest 0.5° the temperature in the light compartment. The flies followed one another, and one by one entered the dark compartment. Frequently a fly returned to the light compartment after a few minutes in the dark, and then after a few seconds returned again to the dark compartment. Sometimes a given fly made three or four such successive reversals. The temperature at which the final reversal of a given fly took place was recorded and considered one observation. After

TABLE I

The effect of illuminance on the temperature at which reversal in reaction to light in Eristalis occurs. See text.

Illuminance in foot candles	Sex	Mean temperature in degrees centigrade ± standard error	Standard deviation ± standard error
250	Male	44.40 ± .023	3.702 ± .159
	Female	45.011 ± .241	3.964 ± .171
600	Male	40.917 ± .228	3.744 ± .161
	Female	43.133 ± .210	3.445 ± .148
800	Male	40.194 ± .182	2.983 ± .128
	Female	41.339 ± .220	3.622 ± .156
1200	Male	41.317 ± .187	3.075 ± .132
	Female	41.506 ± .223	3.660 ± .158
1600	Male	41.828 ± .252	4.148 ± .179
	Female	40.872 ± .247	4.056 ± .175

approximately 35 minutes all the flies had reversed and entered the dark compartment.

Although the temperature throughout the light chamber was probably not uniform the reversal temperatures measured were very close to those where the flies were at a given instant. The thermometer measured the temperature on the floor of the chamber. During most of the periods of exposure the flies were in contact with this floor.

The thermometers used read to one degree. A check on their accuracy revealed that they read approximately 0.2° too high. This error, however, does not invalidate the general conclusions drawn, since it appeared in all the measurements made and is within the limits of error of the experiments.

RESULTS

The results obtained are given in Figure 2 and Table I.

Are the differences between the mean temperatures at which the male flies reversed in the various illuminances significant? According to Pearl (1940, p. 287), "the odds are 369.4 to 1 against the occurrence of a deviation in either the plus or minus direction as great or greater than 3 × S. E. These are long odds, and are conventionally regarded as amounting to practical certainty." The differences between the means at 250 and 600, 600 and 800, 800 and 1200, and at 1200 and 1600 f. c. are, respectively: 9 +, 2 +, 4 +, and 1 + times the standard errors of the differences. This means that the odds against the occurrence from chance of these differences are, respectively: over 400,000,000,000; 79; over 15,770; and 8 to 1. It is therefore evident that the differences between the means at 250 and 600 and at 800 and 1200 f. c., are clearly significant, while the difference between the means at 600 and 800 f. c., is probably not significant. That between 1200 and 1600 f. c., is certainly not significant. Consequently, it is clear that as the illuminance increased from 250 to 1600 f. c., the mean temperatures at which the male flies reversed decreased to a minimum at 800 f. c., and then increased.

As to the females, the differences between the means at 250 and 600, 600 and 800, 800 and 1200, and at 1200 and 1600 f. c., are, respectively: 5 +, 5 +, less than 1, and 1 + times the standard errors of the differences. This means that the odds against the occurrence from chance of these differences are, respectively: over 1,744,000; over 1,744,000; less than 1; and 16 to 1. It is obvious that the differences between the means at 250 and 600 and at 600 and 800 f. c., are clearly significant, while the differences between the means at 800 and 1200 and at 1200 and 1600 f. c. are certainly not significant.

The data presented in Figure 2 and Table I do not permit a definite conclusion as to the reversal temperatures of the females in illuminances of 1200 and 1600 f. c. Apparently the reversal temperature at 1200 f. c. was slightly higher than that at 800 f. c., and the reversal temperature at 1600 f. c. was less than that in the two preceding illuminances. It is, however, probable that there is an error, for some unknown reason, in the mean temperature recorded for female flies at 1600 f. c., since male flies never reversed at higher temperatures than female flies in any other illuminances tested, neither those used in this work, nor that used by Dolley and Golden (1947a), 700 f. c. Moreover, the difference between the mean temperatures recorded for male and female flies at 1600 f. c. is of questionable significance, as is explained later. With the data available it is impossible to decide whether the mean temperature recorded for female flies at 1200 f. c. is erroneous or not.

The differences between the means of the two sexes at the various illuminances: 250, 600, 800, 1200, and 1600 f. c., are, respectively: 1 +, 7 +, 4 +, less than 1, and 2 + times the standard errors of the differences. This means that the odds against the occurrence from chance of these differences are, respectively: 13; over 400,000,000,000; over 15,770; 1; and 143 to 1. It is therefore evident that the differences between the means of the two sexes in illuminances of 600 and 800 f. c., are significant. The differences between the means in the other three illuminances are either not significant or of questionable significance. Consequently, it is obvious that the female flies reversed at a higher temperature than the male flies in illuminances of 600 and 800 f. c. A similar sexual difference was reported by Dolley and Golden (1947a) in Eristalis in an illuminance of 700 f. c.

Discussion

The results presented in this paper show that as the illuminance rises from 250 to 1600 f. c., the reversal temperature of Eristalis decreases to a minimum at 800 f. c. In the males this decrease is followed by an increase. In the females further increase in the illuminance causes no significant change in the reversal temperature. Since, according to Dolley and Golden (1947b), there is a correlation between reversal and lethal temperatures in Eristalis in 700 f. c., the mechanisms involved in both phenomena are related.

The results obtained are not due to differences in relative humidity or in the duration of exposure of the insects to heat. There was variation in these factors in the thirteen or more experiments performed at various times during three years on flies of each sex in each of the illuminances used. Yet when the values of these factors in all the experiments are compared, there is no significant difference in the average value of these factors in the various illuminances.

Summary

1. Observations were made on 2700 young flies in ascertaining the temperature at which *Eristalis tenax* becomes negative to light in the following illuminances: 250, 600, 800, 1200, and 1600 f. c.

2. As the illuminance increases from 250 to 1600 f. c., the mean temperatures at which the male flies reverse decrease to a minimum at 800 f. c., and then increase.

3. As the illuminance increases from 250 to 1600 f. c., the mean temperatures at which the female flies reverse decrease to a minimum at 800 f. c. Further increase in the illuminance causes no further significant change in the mean reversal temperature.

4. In illuminances of 600 and 800 f. c., the temperature at which Eristalis changes in its reaction to light depends upon the sex of the fly. Females cease their positive reaction to light and become negative at higher temperatures than do the males. This difference between the sexes does not exist at the following illuminances: 250, 1200, and 1600 f. c.

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